# National Soil Survey Center

- Soil Survey Research and Laboratory Staff
- Wes Tuttle – Soil Scientist (Geophysical)
- Provide Geophysical Technical Assistance and Training to the States

# ELECTROMAGNETIC INDUCTION

# (EMI)

# EMI

- We associate changes in spatial ECa patterns with changes in soil characteristics.
- Apparent conductivity is a weighted, average conductivity measurement for a column of earthen materials to a specific depth.

# How EMI Tools Work

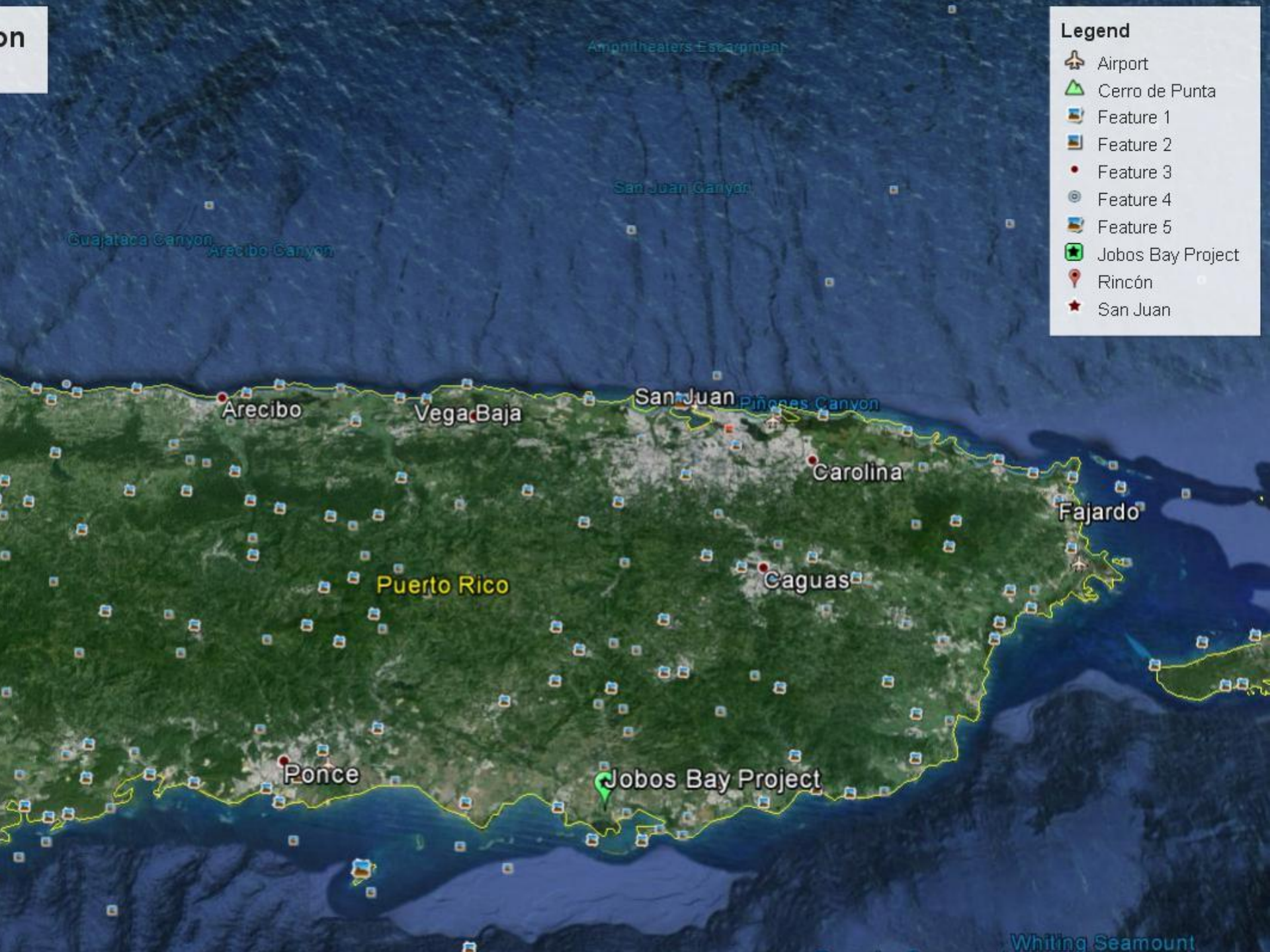
- A primary electromagnetic current is induced into the soil.
- The soil responds with a secondary current which is measured by the EMI instruments.
- We compare the spatial conductivity patterns (ECa measurements) across a given area.

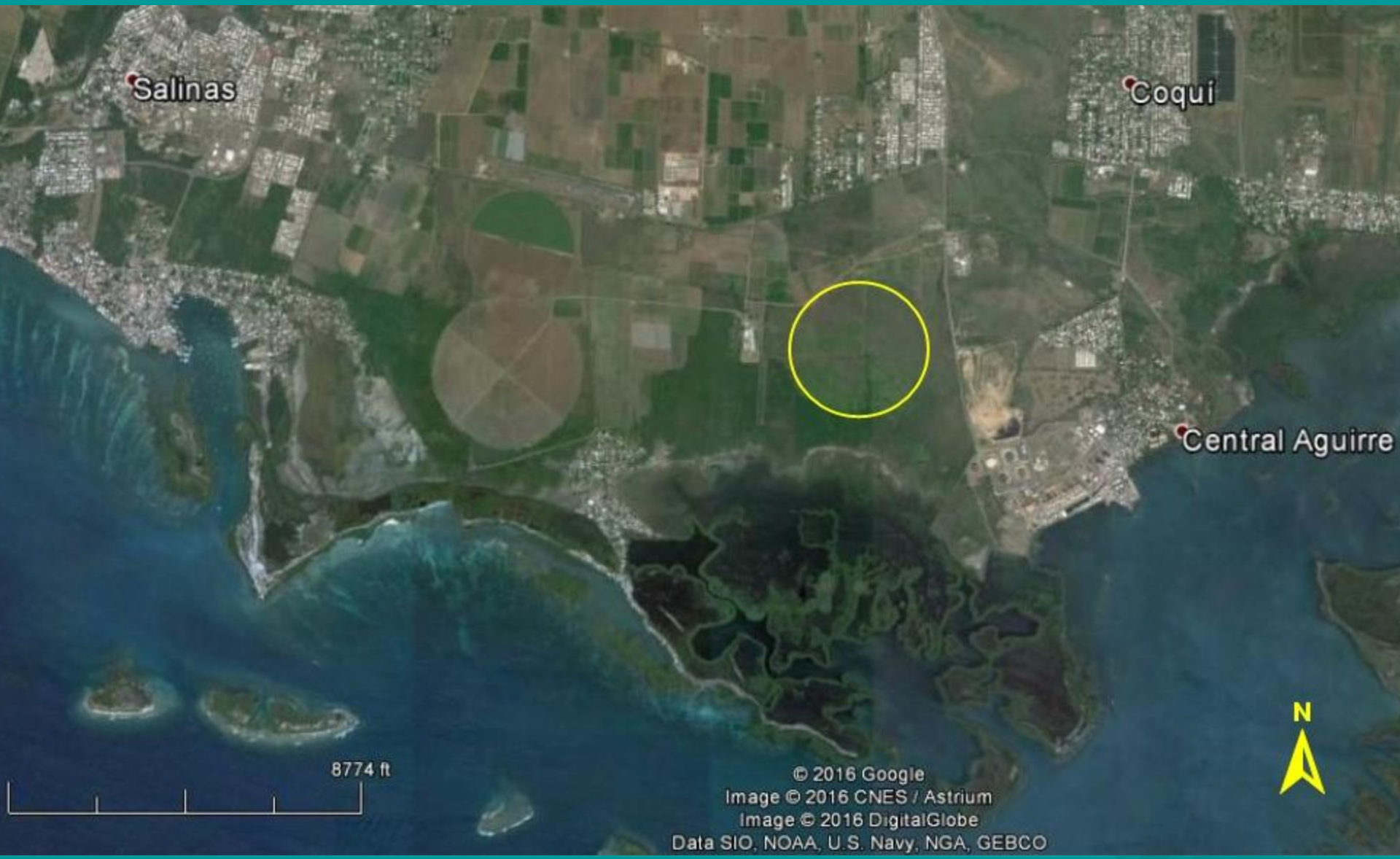

Salinity is not always this easy to observe.
Ute Mountain Ute Indian Reservation
Cortez, CO

# Salinity Survey- Jobos Bay Site, PR

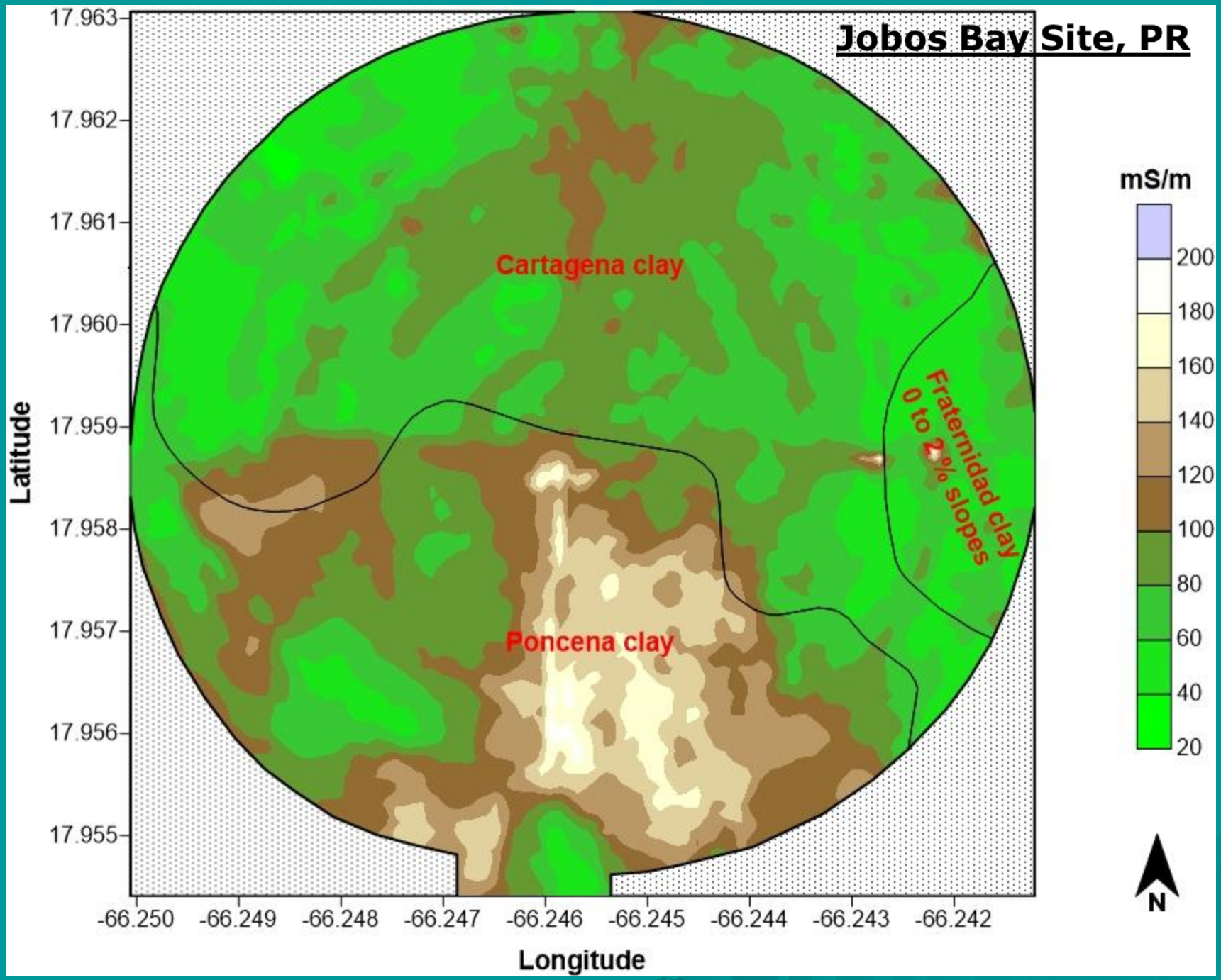
Carmen Santiago and Jorge Lugo

EM-38 meter, Allegro Data Recorder, Trimble AG-114 GPR Receiver


Legend
Airport
Cerro de Punta
Feature 1
Feature 2
Feature 3
Feature 4
Feature 5
Jobos Bay Project
Rincón
San Juan
Amphitheaters Escarpment
San Juan Canyon
Guajataca Canyon
Arecibo Canyon
Arecibo
Vega Baja
San Juan
Piñones Canyon
Carolina
Fajardo
Puerto Rico
Caguas
Ponce
Jobos Bay Project
Whiting Seamount



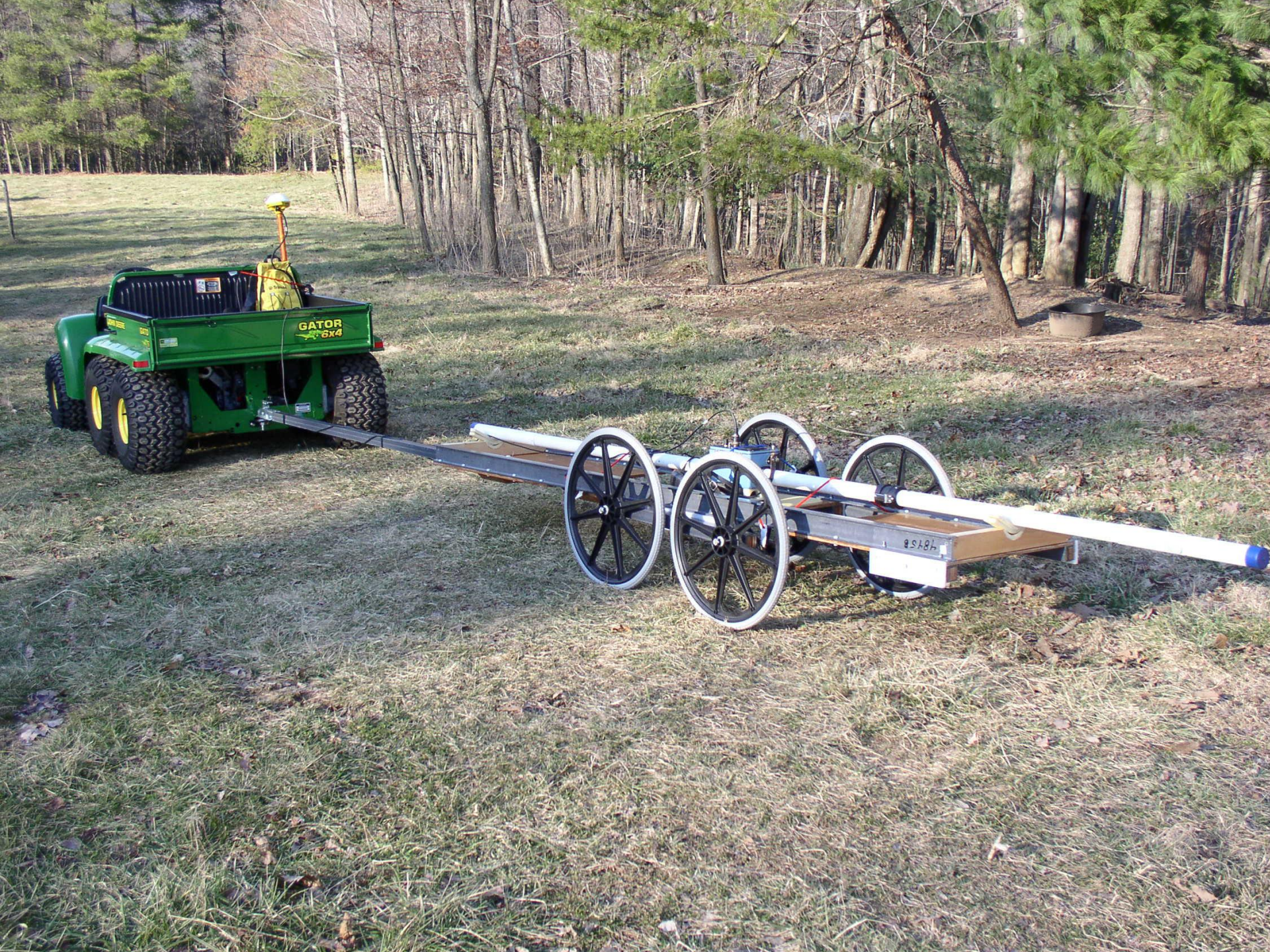

# Jobos Bay Project Site, PR


Jobos Bay Site, PR
Cartagena clay
Poncena clay
Fraternidad clay
0 to 2% slopes
mS/m
200
180
160
140
120
100
80
60
40
20
N
Latitude
17.963
17.962
17.961
17.960
17.959
17.958
17.957
17.956
17.955
Longitude
-66.250
-66.249
-66.248
-66.247
-66.246
-66.245
-66.244
-66.243
-66.242

# EMI Mobile Survey


Mojave Desert
California
Dualem-4 meter


EM-31 meter


GATOR
6x4

# Factors Influencing ECa

- Salt Content
- Clay Content & Clay Mineralogy
- Moisture Content
- Temperature

- The apparent conductivity of soils increases with an increase in soluble salts, clay, and water contents.

- The presence of salts will dominate the other factors.
- When salts are not present, changes in clay content/mineralogy and changes in soil moisture attribute to changes in ECa.
- ECa – measured in millisiemens per meter (mS/m)

# EMI APPLICATIONS

- Map soil salinity and salt water intrusions
- Bedrock topography
- Archaeological investigations
- Locate buried metallic objects (drums, tanks, etc.)
- Quality control tool for soil surveys

# EMI APPLICATIONS

- Map leachate plumes (waste storage lagoons)
- Delineate landfill and trench boundaries
- Map soil and groundwater contaminants
- Precision farming and high intensity soil surveys
- Identify karst bedrock features

# Advantages of EMI (and GPR) techniques over traditional hand augering methods

- Noninvasive
- Fast and expedient method of data collection
- Limited number soil borings and excavations while collecting large amounts of data (ground truthing)
- Develop improved soil-landscape models

# Effects of Salinity on Soils along the Gulf Coast as a Result of Hurricane Sea Water Inundation

# Questions and Concerns

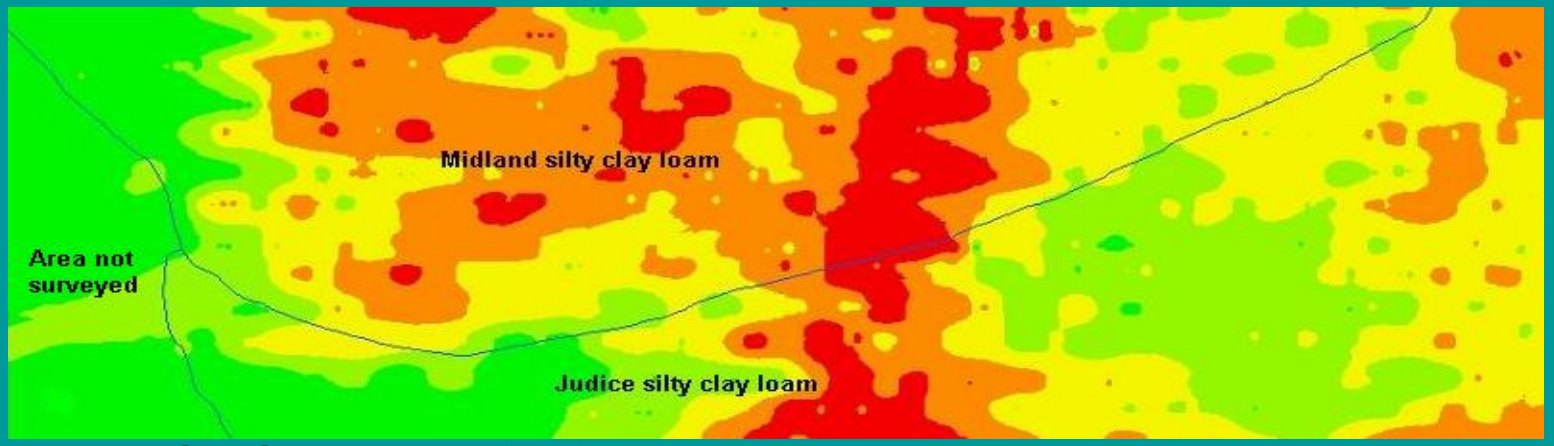
How does salinity in the soil change over time following sea water inundation (hurricanes, tropical storms, etc.)?

How long does it take for the salts to be leached from the soil as a result of precipitation and other factors?

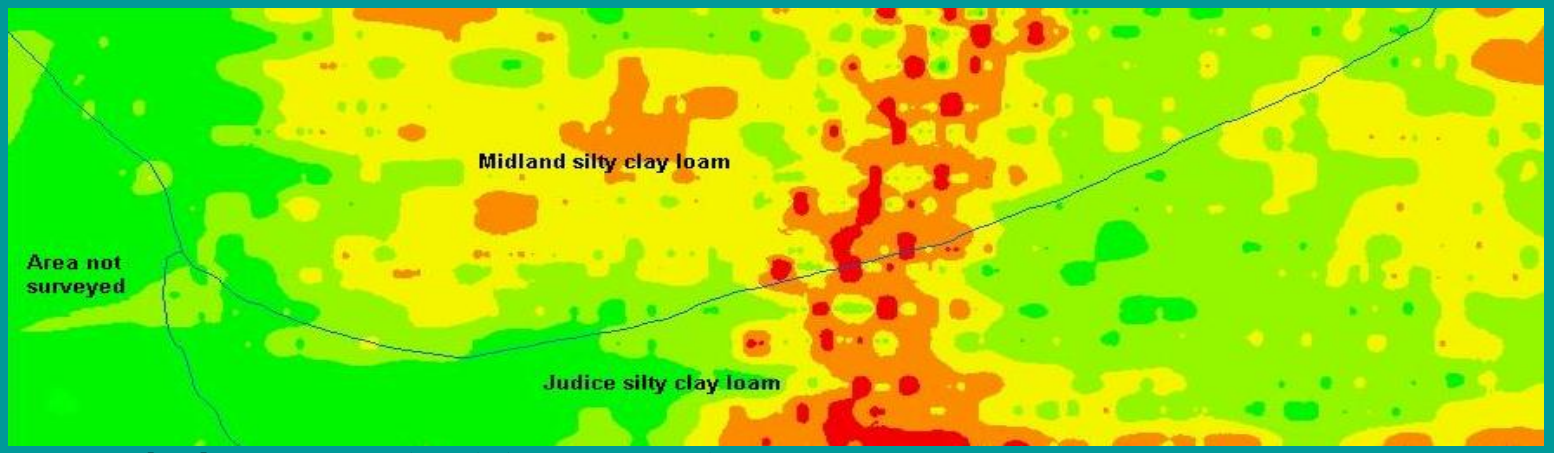
What are “normal” salinity levels----taking into account - repeated flooding events?

Changes in salt concentrations can highly influence plant growth (ex. rice), animals (ex. crawfish) and the overall natural balance in the environment.

How does the duration of salt water inundation affect salt build-up in the soils? (Over topped levees hold the flood waters for prolonged periods…….as far as 30 – 40 miles inland.)

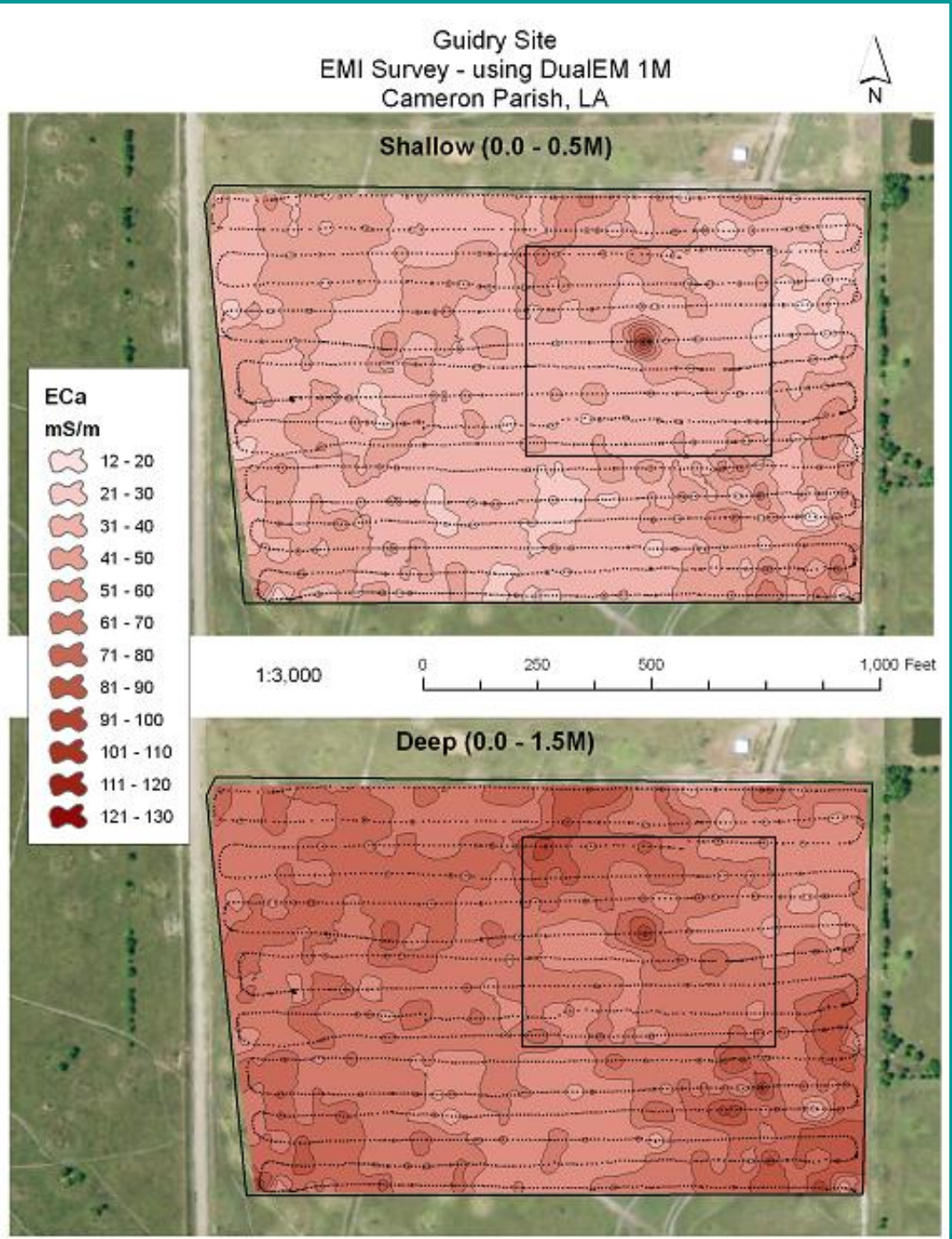



Horizontal Coplanar Geometry (HCP) (0 - 1.5 meters)



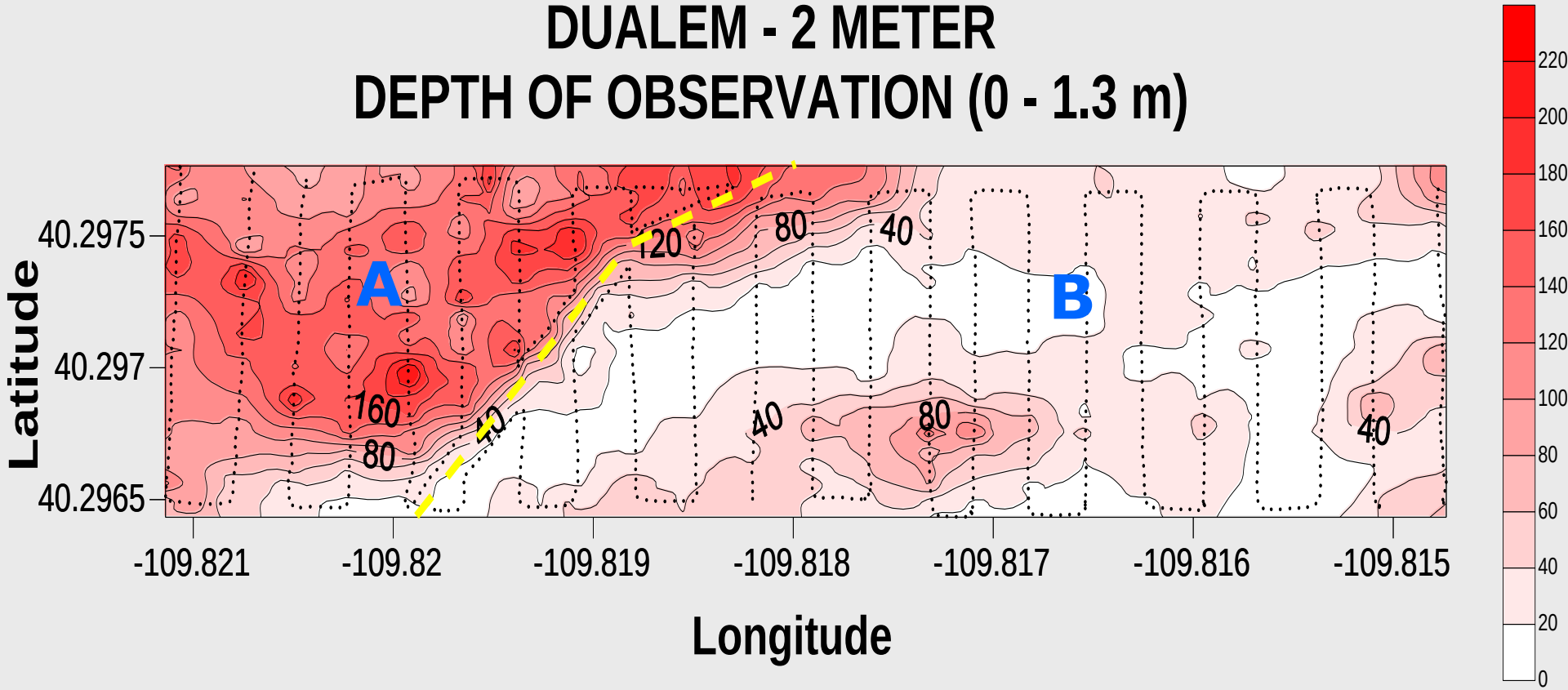

Perpendicular Geometry (PRP) (0 - 0.5 meters)

ArcGIS presentations of an EMI survey completed with the Dualem-1S conductivity meter at the Stelly site and prepared by the NRCS staff in Opelousas, LA. The upper diagram (survey) was collected in the deeper sensing HCP geometry (0 - 1.5 meters) and the lower diagram (survey) was collected in the shallower sensing PRP geometry (0 - 0.5 meter). Areas in red are associated with higher apparent conductivity.




Spatial pattern of ECa measured with the Dualem-1S meter in an area of Morey silt loam and Mowata-Vidrine silt loams at the Guidry site. The upper diagram (survey) was collected in the shallower sensing PRP geometry (0 - 0.5 meter) and the lower diagram (survey) was collected in the deeper sensing HCP geometry (0 - 1.5 meters). ECa is measured in mS/m (millisiemens/meter).

# DUALEM - 2 METER
# DEPTH OF OBSERVATION (0 - 1.3 m)




**Spatial pattern of apparent conductivity measured with the Dualem-2 meter in the PRP (perpendicular) geometry (0 – 1.3 m) in an area of Ohtog-Parahtog complex, 0 to 2 percent slopes, and Parahtog loam, 0 to 2 percent slopes. Apparent conductivity is measured in mS/m (millisiemens/meter).**

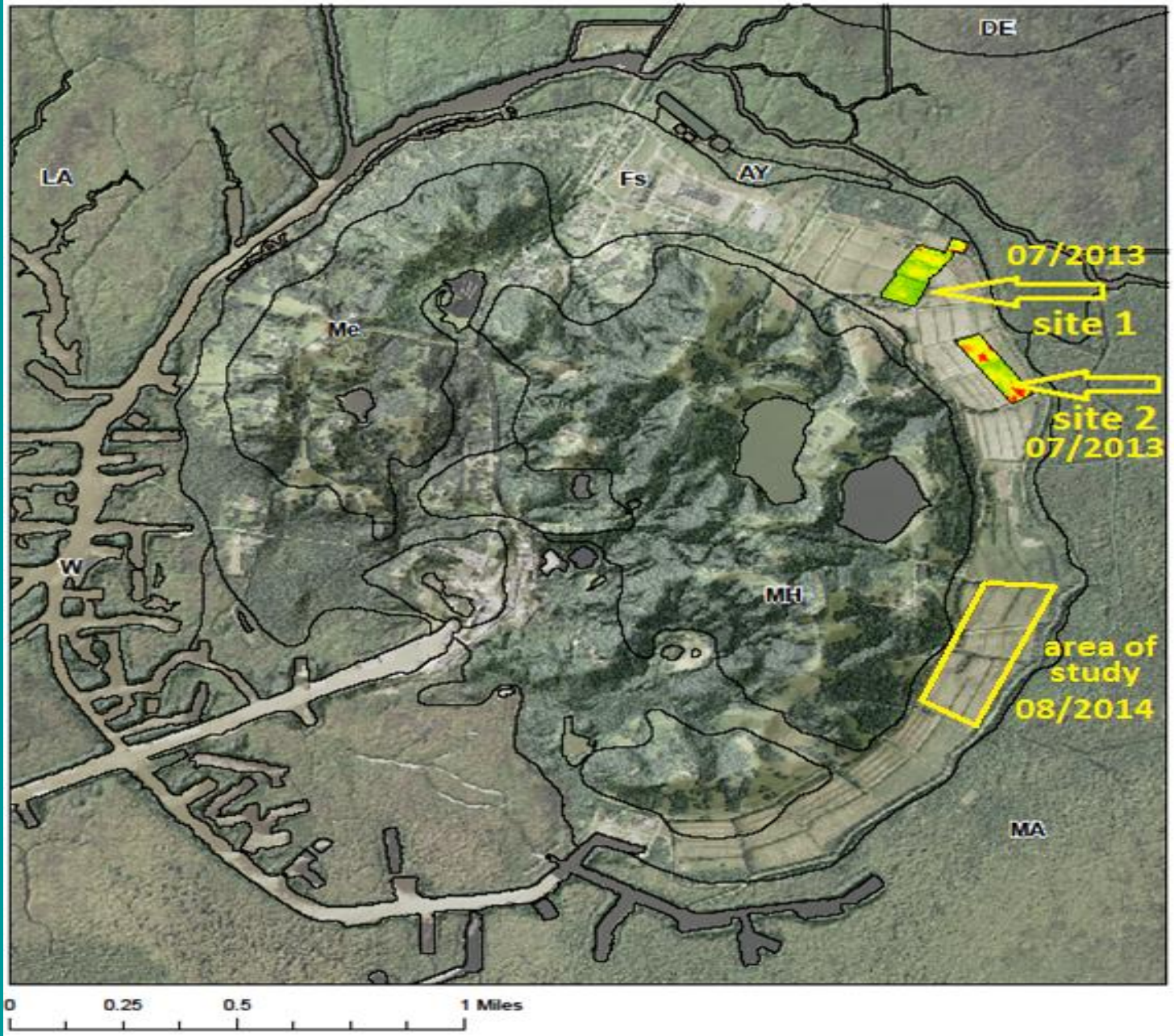
**A**
**Non-irrigated**

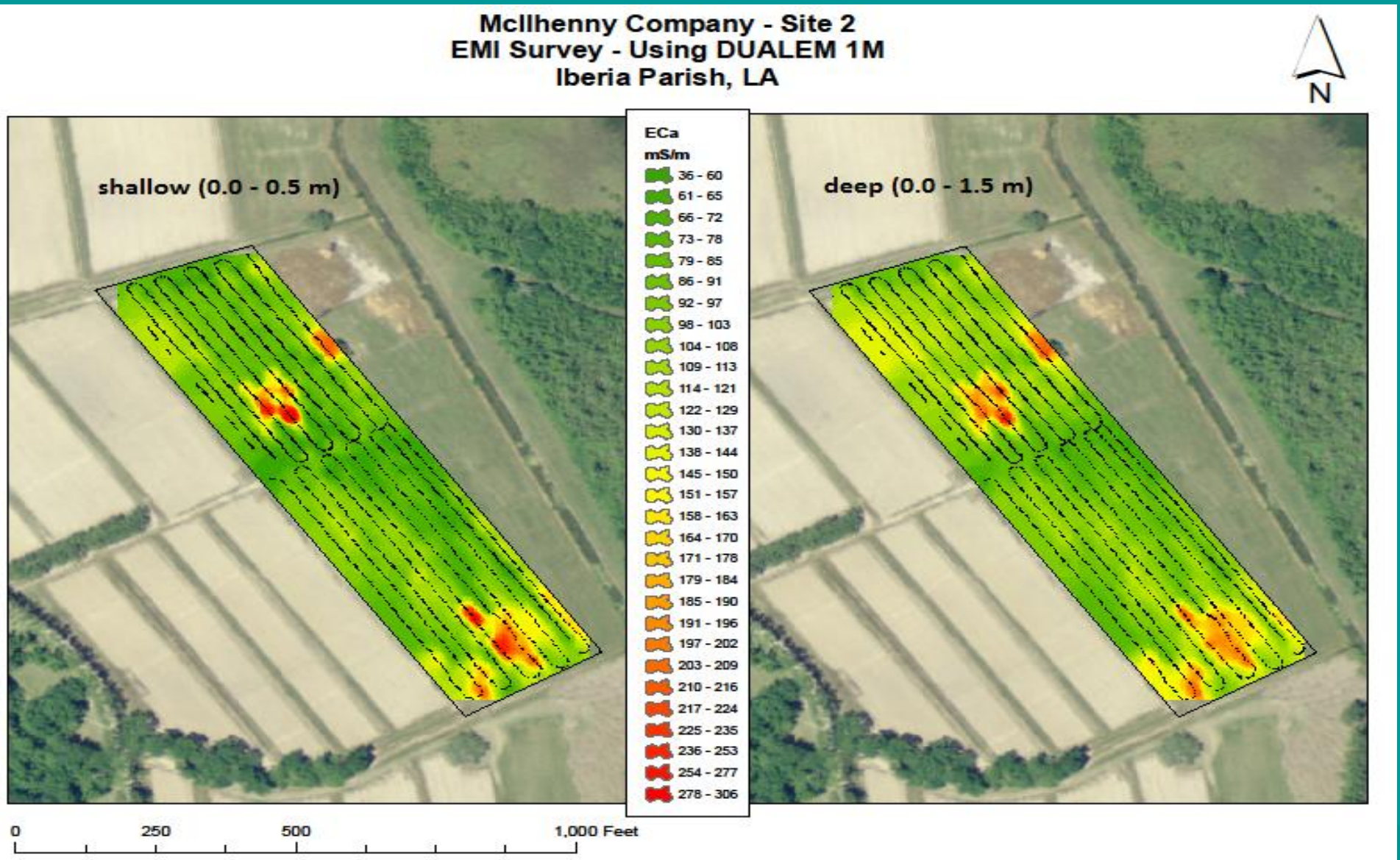
**B**
**Irrigated**

## Salinity Survey (EMI)

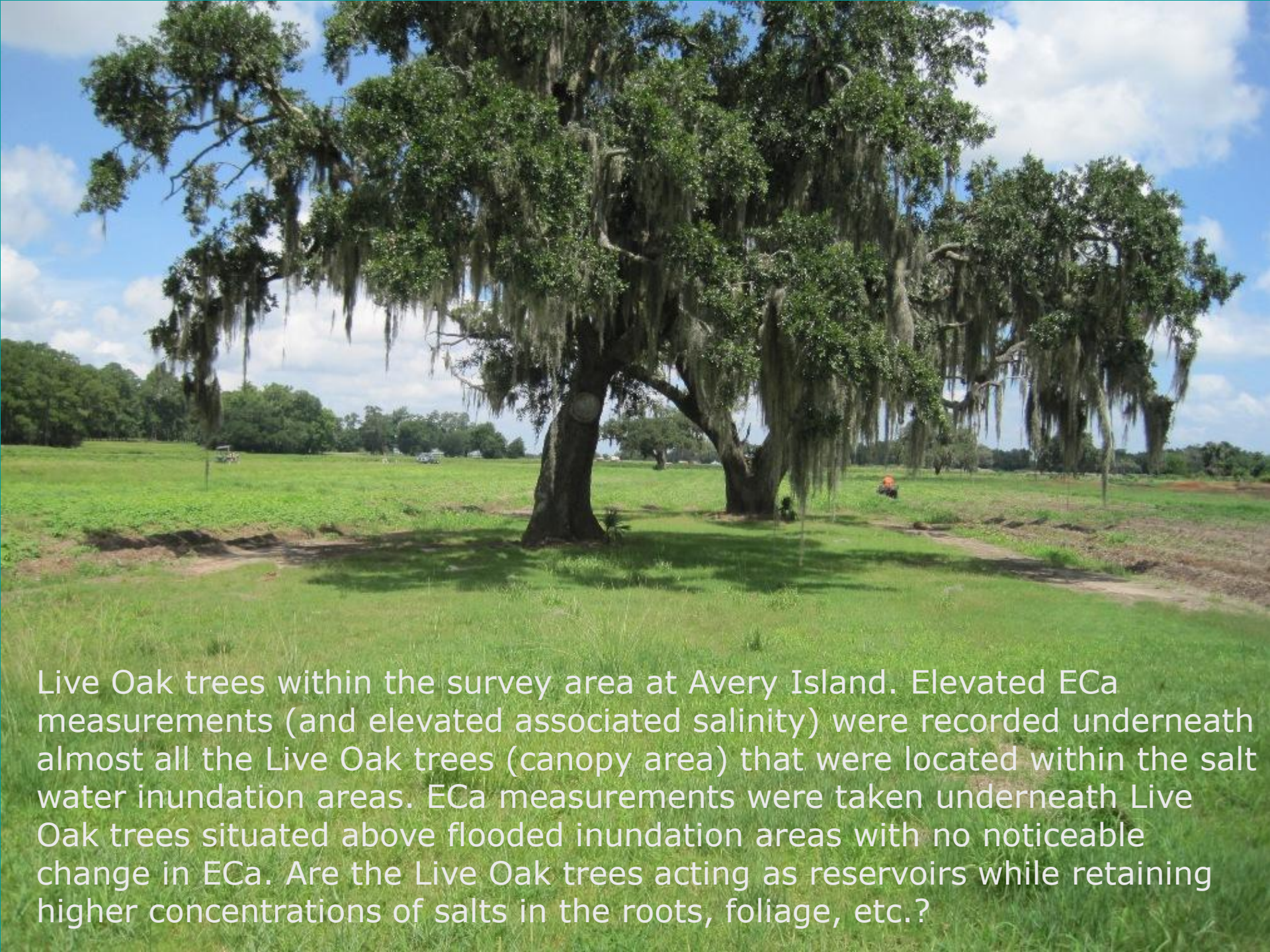
**Uintah County, UT**

# Avery Island - McIlhenny Company
# EMI Survey - using DUALEM 1M
# Iberia Parish, LA

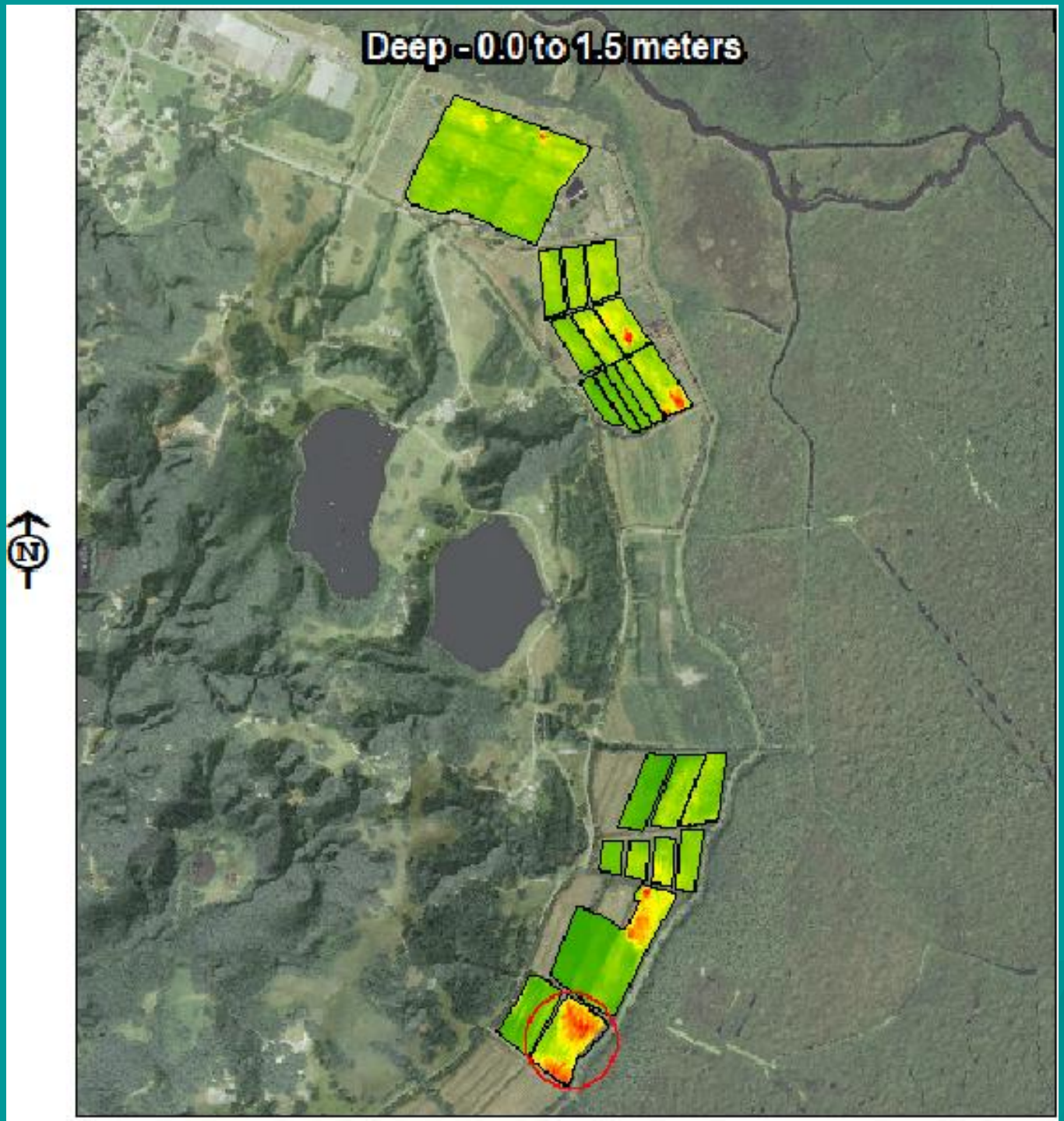




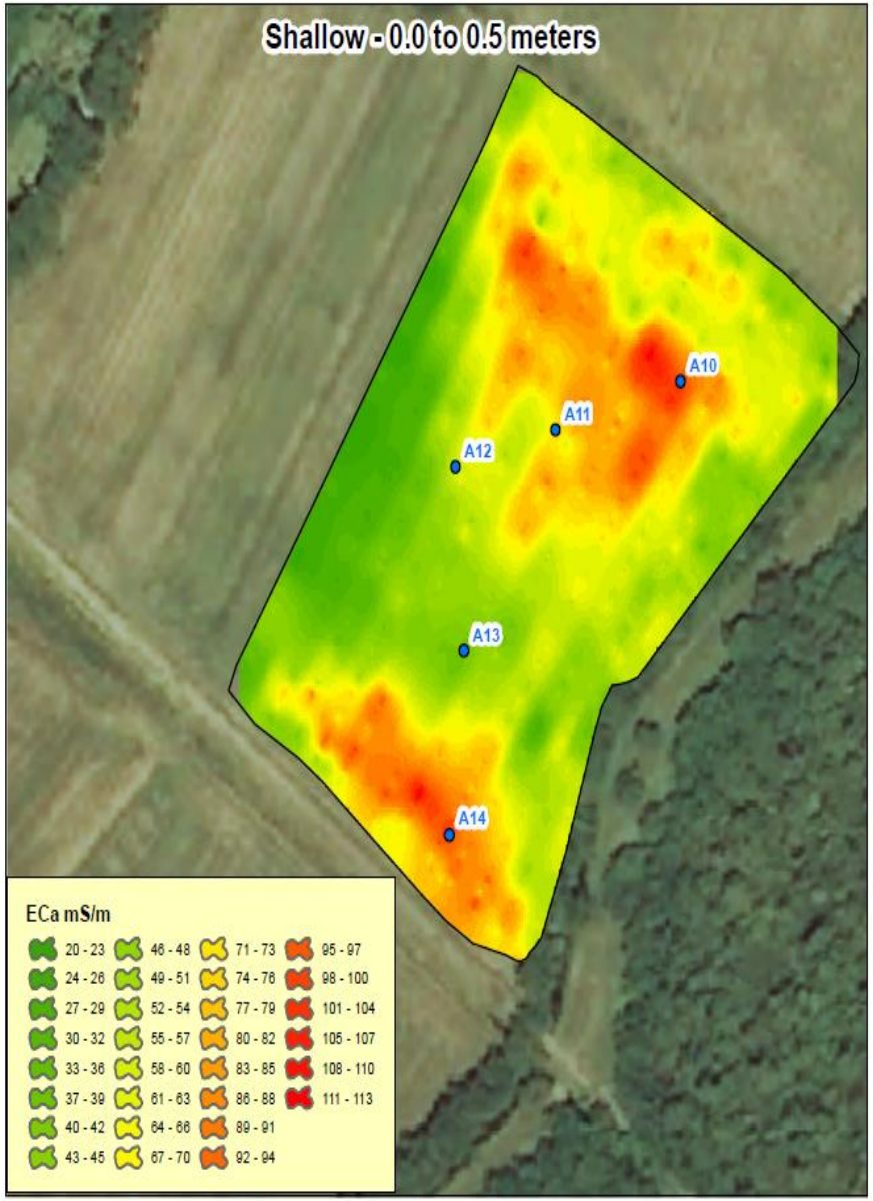

**Avery Island** - Spatial pattern of ECa measured with the Dualem-1S meter in an area of Frost silt loam, overwash, collected in the shallower sensing PRP geometry (0 - 0.5 meters) and deeper sensing HCP geometry (0 - 1.5 meters). Highest ECa measurements (orange and red colors) were collected underneath the canopy or directly adjacent to Live Oak trees. These areas are thought to have higher levels of salinity. ECa is measured in mS/m (millisiemens/meter). This EMI survey/diagram was collected and processed by Mitch Mouton, Resource Soil Scientist, Opelousas, LA.

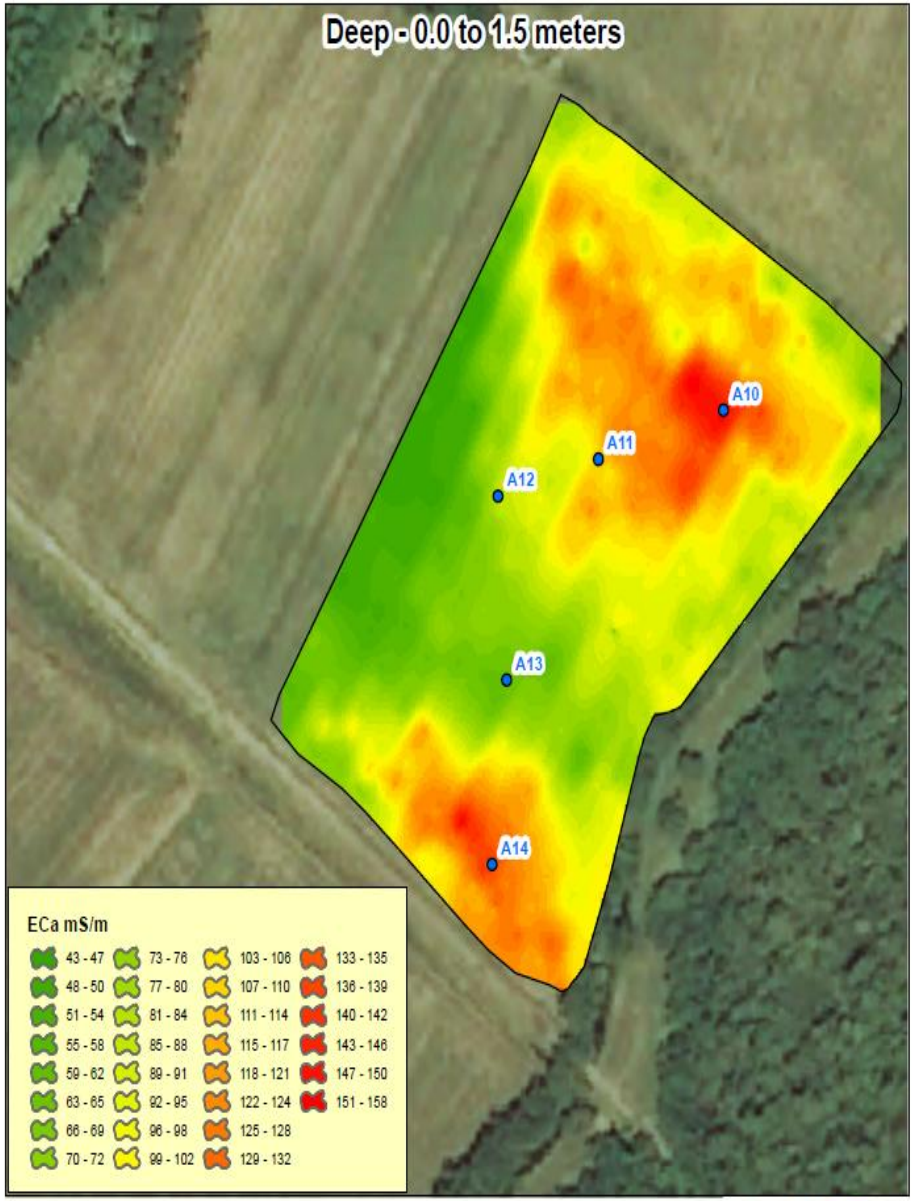


Live Oak trees within the survey area at Avery Island. Elevated ECa measurements (and elevated associated salinity) were recorded underneath almost all the Live Oak trees (canopy area) that were located within the salt water inundation areas. ECa measurements were taken underneath Live Oak trees situated above flooded inundation areas with no noticeable change in ECa. Are the Live Oak trees acting as reservoirs while retaining higher concentrations of salts in the roots, foliage, etc.?


Deep - 0.0 to 1.5 meters
N

# Avery Island, Louisiana
## Handheld EMI Survey - 01/29/2015 (Exhibit C)





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# Stelly Site – Vermilion Parish

A comparison of 2011 EMI data and 2012 EMI data reveals lower average ECa across the survey grid area in both the shallower and deeper sensing geometries (Dualem-1S) for 2012.

2011 – 112 mS/m (Shallower sensing - PRP)

2012 – 82 mS/m (Shallower sensing - PRP)

2011 – 149 mS/m (Deeper sensing - HCP)

2012 – 132 mS/m (Deeper sensing - HCP)

*Average Soil Temperature @ 18 inches

2011 (May) – 25.5 C, 2012 (May) – 25.1 C

# Summary

- In areas inundated from sea water from recent hurricanes, elevated salt contents are thought to decrease over time, largely due to the "flushing" effect from rainfall, changing climatic factors, and to a lesser degree, removal of plant residue. The length of time required to significantly lower salt content is not known and it is hoped that repeated comparative EMI surveys conducted in these salinized soils will help the soils staff gain a better knowledge while dealing with salinity issues.

- Soil texture and slope are thought to highly influence the rate at which salts are removed or "flushed" from the soil profile.

# Making Useful Interpretations Using Geophysical Tools

- EMI and GPR techniques are non-invasive tools, when used in combination with the knowledge of soils and soil properties, can result in more accurate interpretations.

- GROUND-TRUTHING is a NECESSITY!